XXIV INTERNATIONAL CONFERENCE
ON HIGH ENERGY PHYSICS
Munich, August 4 - 10, 1988

Parallel Session 19: The Physics at the Planck Scale

Speaker: V. Rubakov

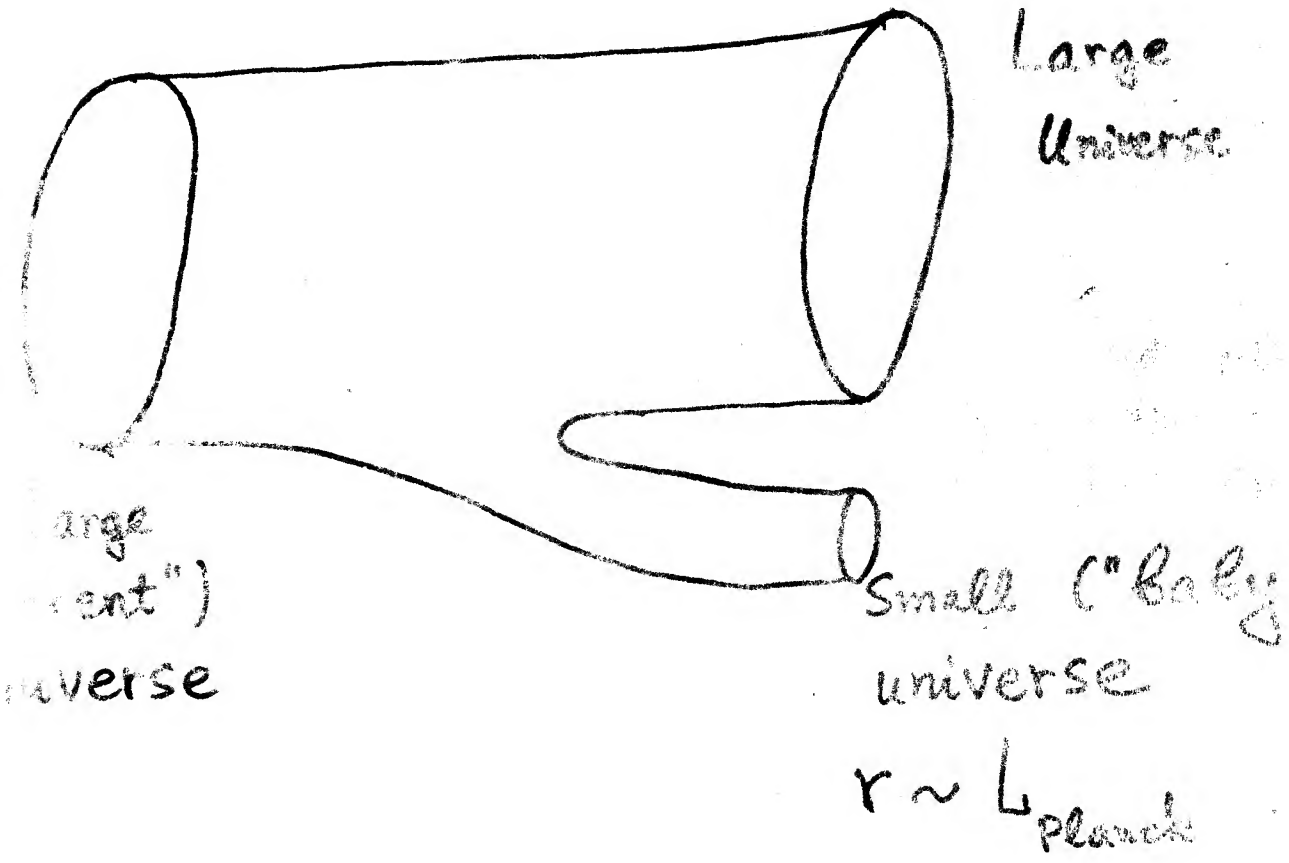
Baby universes and
dynamical Coupling Constants

pages 15

3. - DM

BABY UNIVERSES
AND
DYNAMICAL COUPLING CONSTANT

POSSIBLE ROLE OF TOPOLOGICAL CHANGES



COMPLETE LIST OF RECENT PAPERS:

* S. HAWKING — Phys. Lett (87); Phys. Rev. (88)

* G. LAVRELASHVILI, V. R., P. TINYAKOV — Pisma ZhETF (87); Nucl. Phys. (88)

* S. GIDDINGS, A. STROMINGER — HUTP PREPRINTS (87 8

* S. COLEMAN — HUTP PREPRINTS (88)

* T. BANKS — SANTA CRUZ PREPRINT (88)

ALSO TO APPEAR:

S. GIDDINGS, A. STROMINGER

LAVRELASHVILI, V. R., P. TINYAKOV

I. KLEBANOV, L. SUSSKIND, T. BANKS

V. R., P. TINYAKOV

NOW SEEMS THAT

COUPLING CONSTANTS OF NATURE

ARE "DYNAMICAL VARIABLES".

"DYNAMICAL" DOES NOT MEAN

DEPENDENCE ON SPACE-TIME POINT.

RATHER, "DYNAMICAL" MEANS

THAT ACTUAL VALUES OF

COUPLING CONSTANTS (AS OBSERVED

BY US) ARE DETERMINED BY

"GAP EQUATION" WHICH INVOLVES

OVERALL HISTORY OF UNIVERSE(?)

IN PARTICULAR, BY OUR PAST

AND FUTURE.

IN THIS WAY ONE HOPES TO

EXPLAIN ZERO LOW ENERGY VALUE

OF THE COSMOLOGICAL CONSTANT.

ISSUE IS HIGHLY CONTROVERSIAL

AND SPECULATIVE (AT THE MOMENT?)

NO CONVINCING ARGUMENTS

FAVOURING ZERO L.E. COSMOLOGICAL

CONSTANT ARE GIVEN YET.

PLAN

* DEVIATION: COSMOLOGICAL CONSTANT PROBLEM

* TOPOLOGICAL CHANGES AND OPERATOR COUPLING CONSTANTS

* COLEMAN'S ARGUMENT FOR $\Lambda_{LE.} = 0$

* SELF-CREATION OF UNIVERSES.

NO DISCUSSION OF THIRD QUANTIZATION

(ALTHOUGH VERY RELEVANT AND CONVENIENT (?)).

IATION:
SMOLOGICAL CONSTANT PROBLEM

OBSERVATIONS: $\Lambda_{L.E.} = 0$ AT HIGH PRECISION

L.E. MEANS 10^{28} cm.

* THIS IS LOW ENERGY PROBLEM:

$\Lambda_{L.E.}$ = VACUUM ENERGY DENSITY

RECIEVES CONTRIBUTIONS FROM LOW ENERGY DYNAMICS (QCD VACUUM, etc.)

$\Downarrow$

BARE $\Lambda = 0$ (DUE TO, E.G., HIGH ENERGY SUPERSYMMETRY) IS NOT ENOUGH

FANTASTIC FINE TUNING OF BARE Λ IS REQUIRED TO SET $\Lambda_{L.E.} = 0$

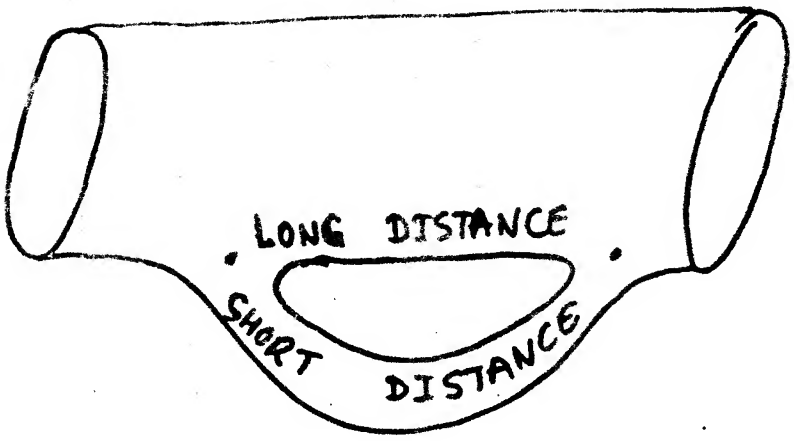
OBSERVED $\Lambda_{L.E.}$ MUST SOMEHOW BE DETERMINED BY *GLOBAL PROPERTIES* OF UNIVERSE

A. LINDE '88

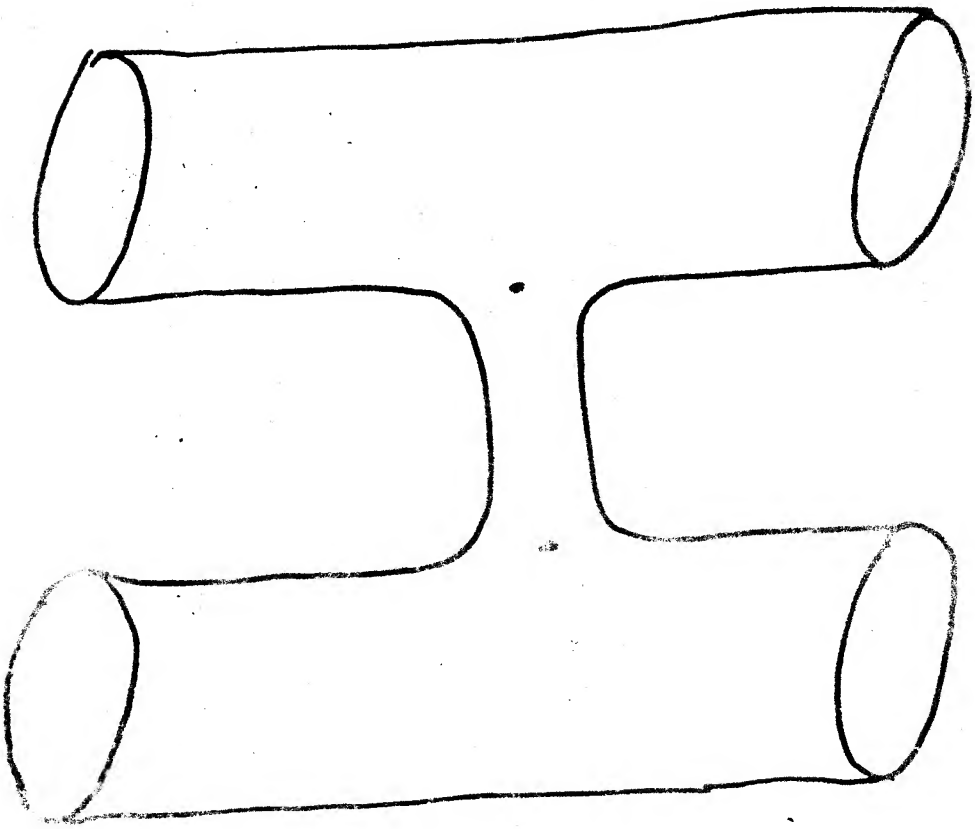
$\Downarrow$

NON-LOCAL INTERACTIONS ARE NEEDED

...D PROVIDED BY
TOPOLOGICAL CHANGES:



OR/AND



TOPOLOGICAL CHANGES AND OPERATOR COUPLING CONSTANTS

* ENERGY, MOMENTUM, ELECTRIC CHARGE, ETC. OF A CLOSED UNIVERSE ARE ZERO

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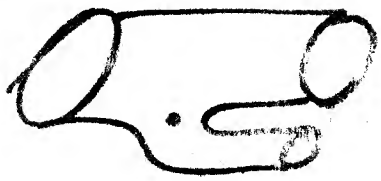
CONSERVATION LAWS IN PARENT UNIVERSE ARE NOT VIOLATED

* MINKOWSKI SIGNATURE MANIFOLDS OF THIS SORT ARE SICK (SINGULARITIES OR CAUSAL ANOMALIES)



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EUCLIDEAN SIGNATURE MANIFOLDS (?)

⇓

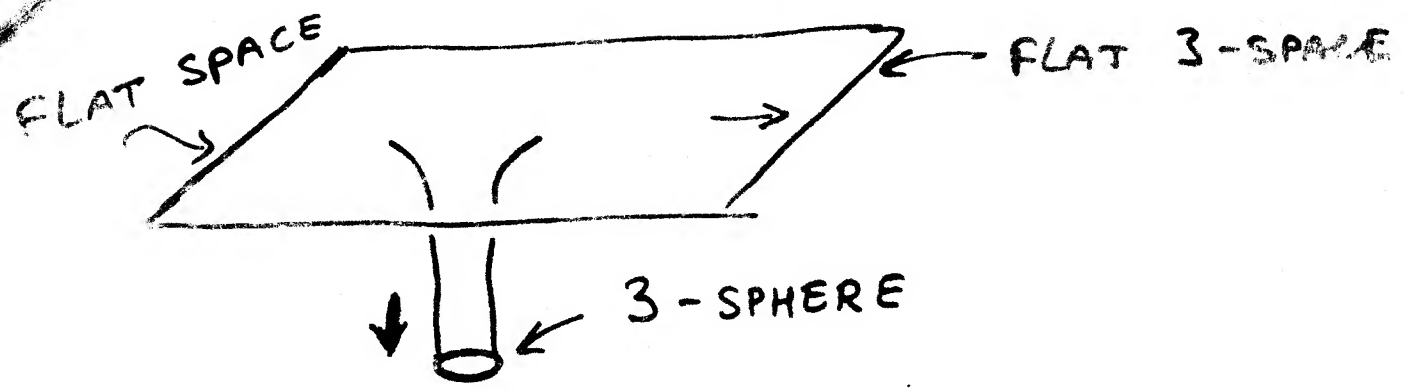
TUNNELING EVENTS

EUCLIDEAN GRAV. ACTION NOT POSITIVE

...ITATIONAL INSTANTONS

GIDDINGS AND STROMINGER (87)

(GRAVITY + $H_{\mu\nu\lambda}$)

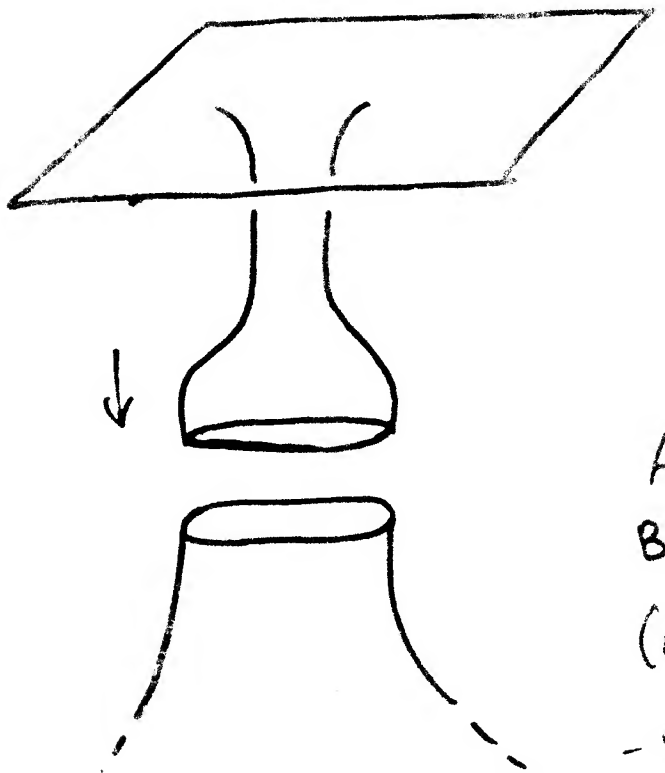


ANALYTICAL CONTINUATIO
BABY UNIVERSE COLLAPSES
DOWN TO SINGULARITY

(BABY DOES NOT GROW UP

* V.R. AND TINYAKOV (88)

(GRAVITY + $H_{\mu\nu\lambda}$ + SCALAR FIELD)



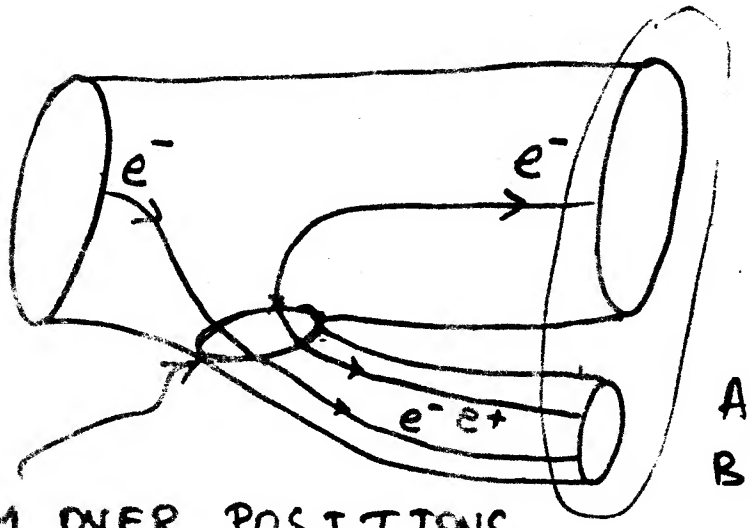
ANALYTICAL CONTINUATIO
BABY UNIVERSE EXPANDS

(AND CAN BECOME PARE

...DER FIRST G.-S.

PARTICES INTERACT WITH INSTANTON

HAWKING '87
LRT '87



SUM OVER POSITIONS
+ A WORMHOLE

ANOTHER TYPE OF BABY UNIVERSE CREATED

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SYSTEM HAS EXTRA DEGREES OF FREEDOM (# OF SMALL UNIVERSES OF GIVEN TYPE)

VIEWED FROM LARGE SCALES

Coleman '88

$$\text{HAMILTONIAN} = H_0 + \sum_i \left(\int \theta_i(x) d^3x \right) (a_i^\dagger + a_i)$$

(WRT TIME OF LARGE UNIVERSE)

θ_i = LOCAL HERMITEAN OPERATOR

$a_i^\dagger$ = OPERATOR CREATING BABY UNIVERSE of i-th type

$\theta_i = C_0, C_1 \bar{e}e, \ldots$

(LORENTZ INVARIANCE ALSO REMAINS)

COUPLING CONSTANTS :

$$\lambda_i^{eff} = \lambda_i^{bare} + C_i \left(a_i^+ + a_i\right)$$

$$H = \sum_i \lambda_i^{eff} \int \theta_i \, d^3x$$

λ_i^{eff} not NECESSARILY COMMUTE?

Model: Giddings, Stromінger '88

(If not commute ⇒ non-local theory,

$[\mathcal{H}(\vec{x}), \mathcal{H}(\vec{y})] \neq 0$).

ASSUME λ_i^{eff} commute

⇓

DIAGONALIZE $(a_i^+ + a_i)|q\rangle = q_i |q\rangle$

⇓

$\lambda_i^{eff} = \lambda_i^{bare} + C_i q_i$ in sector $|q\rangle$.

's are like θ_{QCD}.

COUPLING CONSTANTS ARE NOT YET DYNAMICAL
Nevertheless one can attempt to "determine" preferred values of λ_i^{eff}.

IN GENERAL, STATE IS

$\sum_q C_q |q\rangle$ (measure q ⇒ know where you are)

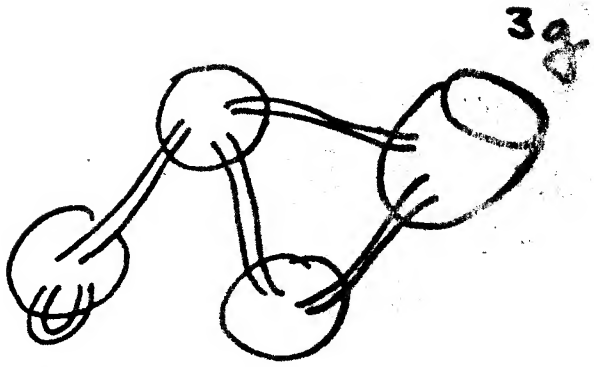
C_q be peaked at some values of $\{q_i\}$?

MAN'S ARGUMENT (88)

Close to Hawking '8

C_q are given by Hartle - Hawking prescription

$$C_q[{}^3g] = \sum_{\substack{\text{EUCLIDEAN} \\ \text{4-geometries} \\ \text{with the only} \\ \text{boundary } {}^3g}} e^{-S_E({}^3g, \lambda_{eff})}$$



$$= \sum_{\substack{\text{smooth} \\ \text{geometries}}} e^{-\Gamma_E({}^3g, \lambda^{eff}_{L.E.})}$$

SUM IS ASSUMED TO BE SATURATED BY SADDLE-POINTS OF Γ_E (SOLNS. TO EUCLIDEAN EINSTEIN EQNS.)

$$\Gamma_E = \int d^4x \sqrt{g} \left(\Lambda_{L.E.} - M_{Pl}^2 R + \ldots \right)$$

↖ Higher derivs

ONE SADDLE POINT:
4-SPHERE, $R = \text{const}\ M_{Pl}/\sqrt{\Lambda_{L.E.}}$

$$\Gamma_E(4S) = -\ \text{const}\ \frac{M_{Pl}^4}{\Lambda_{L.E.}}$$

TE GAS:

$$\tilde{q} \propto e^{e^{-\Gamma_E}} = e^{e^{+\text{const.} \frac{M_{pe}^4}{\Lambda_{L.E.}}}}$$

SHARPLY PEAKED AT $\Lambda_{L.E.} = +0.$

MAIN DRAWBACK:

THE WHOLE ARGUMENT IS BASED UPON NON-POSITIVENESS OF EUCLIDEAN GRAVITATIONAL ACTION,

WHICH IS UNDESIRABLE FEATURE OF EUCLIDEAN QUANTUM GRAVITY.

THERE ARE ALSO PHYSICAL Λ REASONS NOT TO BELIEVE EUCLIDEAN QUANTUM GRAVITY IN THIS CONTEXT

Linde '85
LRT '85

-CREATION OF UNIVERSES

are instantons describing creation of expanding Universes

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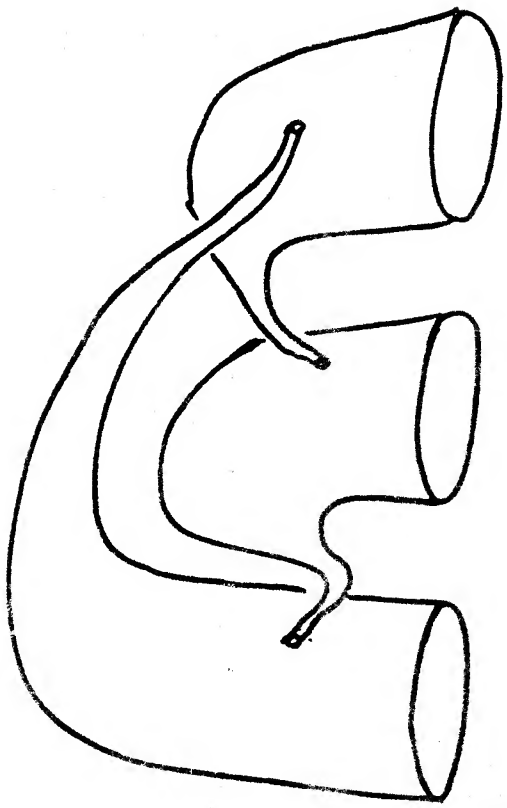
SELF-CREATION OF UNIVERSES IS POSSIBLE:



No overall time for the whole SYSTEM: TIME IS CREATED TOGETHER WITH OF A GIVEN UNIVERSE THIS UNIVERSE.

UNIQUE BOUNDARY CONDITION: THERE ARE NO UNIVERSES WITH VERY SMALL RADII. (CREATION FROM NOTHING).

...ON OPERATORS OF BABY PARENT UNIVERSES.

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COUPLING CONSTANTS ARE TO BE DETERMINED BY SELF-CONSISTENCY

TRULY DYNAMICAL COUPLING CONSTANTS.

WHY STATE VECTOR COULD BE PEAKED AT $\Lambda_{L.E.} = 0$?

GUESS: BECAUSE UNIVERSE WANTS TO HAVE LARGE (MINKOWSKI) SPACE-TIME VOLUME.

# of created universes $\mathcal{L}$ Space-time volume of one universe

⇓

the larger the space-time volume, the number of big universes ⇒ the larger the probability to be in one of them

Negative $\Lambda_{L.E.}$ ⇒ Volume $\sim \frac{1}{|\Lambda_{L.E.}|}$

Positive $\Lambda_{L.E.}$ ⇒ Universe expands rapidly, space-TIME volume is again small

⇓

$\Lambda_{L.E.}$ is going to be peaked at zero.

e) COUPLING CONSTANTS ARE DETERMINED BY THE LARGEST (IN THE SENSE OF MINKOWSKI SPACE-TIME VOLUME) PART OF THE HISTORY OF TYPICAL UNIVERSE

ANOTHER POSSIBILITY: STATE VECTOR IS NOT PEAKED $\Rightarrow$ ANTHROPIC PRINCIPLE CAN HELP.